# ADVANCE FIRE PROTECTION DELUGE SYSTEM

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# IRE PROTECTION DELUGE SYSTEM

**STEVEN P. WELLS - Project Manager**
**ROBERT A. LOYD - Technical Advisor**

## 1. Introduction:

a. Energetic materials which burn or deflagrate pose a Significant risk to munitions production, maintenance and renovation operations, as reflected by loses suffered by the U.S. Army Armament Munitions and Chemical Command between 1988 and 1992. These cost totaled $9,500,000 and involved three deaths, nine serious injuries, and severe property damage. Non-quantifiable costs included environmental, legal, investigation, lost production, and mandated improvements. DOD and private ordnance facilities continue to suffer losses.

b. In DOD and private ordnance facilities fire detection and suppression systems have not fully kept up with advances in new technologies. Many existing ultra high-speed deluge systems were improperly designed and installed. Such problems have been identified and documented by accident investigation teams, surveys, staff assistance visits and project reviews. False alarms and activations have occurred with serious impact on ordnance operations. Response times of existing detectors are not consistent and may vary over a large range. The definition of deluge system response time is incomplete and not commonly agreed upon. Further complicating the existing situation is the lack of technical guidance, performance standards, and the loss of personnel qualified to design, install and maintain ultra high-speed deluge systems.

## 2. Objective:

a. The objective of this project is to develop and demonstrate an advanced ultra high speed fire protection deluge system that will provide a 95 percent reduction in false alarms and a 75 percent reduction in response time, compared to current systems installed at Army ordnance facilities.

b. In this project, the research effort is expanding on previous work. This includes the development of false alarm stimuli data which has caused significant problems with existing UV (ultraviolet) fire detectors. Validation and testing of new optical fire detector technology including multi-band IR/IR (infrared) and IR/UV detectors. The research effort also included validating the ability to detect pyrotechnic and propellant flash fires, designing, operationally testing and validating a prototype system, and foremost, introducing new and superior technologies which enhance the capability of the current systems to react faster to burning energetic materials. The feasibility of applying the new technologies developed by this project to tanks, armored personnel carriers, armored resupply vehicles and other armored vehicles will be examined, subsequently by the Army.

c. An additional objective of this project is the optimization of existing systems through upgrades, modifications, technical enhancements and operational procedures.

## 3. Approach:

a. One of the main goals of this project is to take advantage of the ideas and improvements that had been made by innovative plant technicians and engineers over the years. One of the suggestions was to locate the water and detector as close to the source of the burning hazard as possible, taking into consideration cost and safety. As a result of this thinking process, detectors, sphere and follow-on water were all placed over a test table at a minimum height of 36 inches. This would simulate a typical work station. For the larger amounts of material burns (l-3 pounds of pyrotechnic composition), the table is moved aside and the materials placed on the floor directly under the sphere. It is 71 inches from the bottom of the sphere to the floor. This configuration was designed to simulate a mixing operation. The sphere was placed on an adjustable rack to make adjustments as required to compensate for differences in propagation and burn rate of different materials.

b. Off-the-shelf high rate discharge spheres were selected because it was believed that they could be successfully coupled with fast acting detectors and deliver water quickly and effectively to a burning hazard, since the location of the hazard was known. Two sizes are being tested; a 10 liter and 30 liter container. These spheres were selected because they can be pressurized with nitrogen to about 900-psi static pressure. An initial setting of 500 psi of nitrogen was selected and has been ideal throughout the evaluations to date. The spheres are discharged via an internal squib (actuator) activated by a signal from the detectors through a control panel. Because the exploding actuator briefly creates a much higher internal pressure within the sphere, the water is discharged at about twice the static pressure. A screen and spreader break the water into small-atomized particles, assuring even distribution and collection of the residual fragments of the squib. A follow-on water system consisting of dual nozzle pressurized water assures additional cooling and suppression of the burning pyrotechnic or propellant hazard. In all tests conducted to date however, the sphere has successfully controlled and extinguished the burn without the supplemental follow-on water. The atomized water poses no hazard to personnel.

c. Three dual band optical fire detectors are being tested based on their advertised characteristics as being false alarm resistant and their ability to detect burning pyrotechnic materials in less than 5 milliseconds. They are: Spectrex 62002 (SAFE)-UV/IR, Fire Sentry (SS2-AM & SS2 AML)-UV/IR, and the Dual Spectrum Santa Barbara IR/IR. Single band Detector Electronics UV fire detectors are also being used to provide a baseline. Most of the detectors presently used in Army ordnance facilities are Detector Electronics UV detectors. Although advertised as possessing false alarm resistance and ultra high-speed characteristics, these single and multi-band detectors have not been tested against these burning energetic materials. Such materials are generally not available to private companies.

## 4. Testing:

a. The prototype system was tested with l/4 to l/2 pound samples of different pyrotechnic compositions, propellants, and high explosives. They range from benign to very energetic compositions including smoke, first fire, illumination mixes and IR decoy flare composition. Each material was tested with each of the four detectors. The Detector Electronics units were used as a baseline for comparisons. Each test was repeated three times to ensure the results were statistically valid. Each sample was placed in a pile. An electric match with several grains of smokeless gunpowder was used as an ignition source for the “burn”. They were placed on the

bottom of the pile.  Most Phase I tests were done with the l/4 to l/2 pound samples with the 10-liter (3 gallons of water) sphere pressurized to 500 psi.

b.  The three multi-band optical detectors and the single band UV Detector Electronics unit were subjected to extensive false alarm stimuli testing.  These stimuli included floodlights, flashlights, neon drop lights, sunlight, chopped light (flood light and drop light sources), drill motor (with sparks), MIG and stick welding (mild steel, aluminum, stainless steel) with various currents and rods.  Distances for welding operations included two, three, six, nine and twelve foot distances from the detectors.  The UV detector was subjected to welding operations at distances beyond twelve feet including outside welding at over twenty-four feet.

**5.  Results:**

a.  All testing was conducted IAW the test plan.  All tests were conducted using train Explosive Ordnance Disposal (EOD) and laboratory technicians.  Extensive checklists were developed and followed.  All tests were recorded on standard speed video and high-speed video (1,000 frames per second) with a camera borrowed from the U.S. Army.  Each event (test) was written up separately and the events recorded in a logbook.  Data recorded for each event included times from detectable event to sphere discharge, detectable event to sphere water on flame, detectable event to sphere water on table, detectable event to follow-on water and detectable event to fire suppression.  All of the data was directly measured from observations recorded on the high-speed camera and a data recorder.  Test personnel also recorded observations in their field notes.  Although each test was configured to test a particular detector's ability to "see" an event and activate the system, a measurement of how fast the other detectors reacted to the same event was also done.

b.  In every test conducted the burning material was detected and extinguished.  In most cases considerable amounts of unburned residue remained on the table, Lexan shield around the table and on the floor indicating that the system was catching and interrupting the burn before further propagation occurred.  A few of the materials, however, were water-soluble (smoke mixes for example) and dissolved in the residue water remaining from the sphere.  Each material burned produced varying response times for the system with energetic materials (red lead and M206 mix) producing the fastest response.  The slower times usually occurred with the smoke mixes, which partially obscured the detector's field of view.  The smokes also required more time to "ramp up" to an equivalent size fire of M206 IR flare mix, for example.  One M206 IR flare fire grew to a diameter of 31 inches in less than two milliseconds.  The same fire from a smoke mix would require 300 milliseconds to grow to this size.

c.  The spectral emissions of 17 energetic materials were measured, deterring the energy output in the infrared and ultraviolet regions.  The emission data is used to optimize the detector parameters for each energetic material to reduce detection response time and reduce false alarms.

**6.  Phase II Testing:**  Phase II of this project started in early 1998.  It includes testing with larger sample sizes (3-5 pounds).  In addition to the materials on hand, additional types of pyrotechnic compositions, propellants, and high explosives are being tested.

**7.  Lake City Army Ammunition Plant:**

a.  Test personnel modified the prototype design to fit a pyrotechnic charging machine at Lake City Army Ammunition Plant.  It was tested with pyrotechnic material provided by Lake

City Army Ammunition Plant. The modified system is being installed at Lake City Army Ammunition Plant.

b. Lake City Army Ammunition Plant representatives prepared a separate paper on this effort.

**8. Summary:**

a. This project provides a way to significantly improve the safety of ordnance workers, equipment, and facilities. The prototype can be used as a stand-alone system or the detectors can be used to optimize existing deluge system. The following charts provide a brief summary of the work to date.

b. A final report will contain with details on the prototype system including drawings and specifications. A handbook on the design, installation, and maintenance of ultra high-speed deluge systems will also be prepared.

**For additional information contact: Mr. Robert Loyd, Project Technical Advisor or Mr. Steven Wells, Project Manager.**

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# ADVANCED FIRE PROTECTION DELUGE SYSTEM

## BACKGROUND

- DEATHS & INJURIES IN DOD AND PRIVATE ORDINANCE FACILITIES
- FACILITY AND EQUIPMENT DAMAGE
- DETECTOR FALSE ALARMS
- INEFFICIENT DETECTION/ SUPPRESSION SYSTEM

## GOALS

- OPTIMIZE DETECTOR RESPONSE TO FLAME
- REDUCE FALSE ALARMS
- INCREASE SUPPRESSION SPEED
- IMPROVE WORKER SAFETY
- FINALIZE PROTOTYPE SYSTEM

## APPROACH

- MULTI-WAVELENGTH FLAME DETECTION
- RE-DESIGN WATER DELUGE SYSTEM
- EVALUATE DETECTOR FALSE ALARM IMMUNITY
- EVALUATE PYROTECHNIC SPECTRAL EMISSIONS

# ADVANCED FIRE PROTECTION DELUGE SYSTEM

DEFENSE AMMUNITION LOGISTICS ACTIVITY

## MATERIALS TESTED

### PHASE I

- ILLUMINATING COMPOUND FOR MK18 PROJECT LOAD
- MK25 STARTER COMPOSITION
- M18 YELLOW SMOKE AND GREEN SMOKE
- MK875 RED LEAD DELAY COMPOSITION
- M206 IR FLARE
- FIRST FIRE MIXTURE - Type I
- M125 ILLUMINATE COMPOSITION

### PHASE II

- RS-40 & RS-41 INCINDIARY COMPOSITION
- R-440 DIM TRACER COMPOSITION
- HY-SKOR 700X, M14, JA-2, & LKL PROPELLANT
- PBX-9501, PBX-9502 & LX-17 HIGH EXPLOSIVE

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# ADVANCED FIRE PROTECTION DELUGE SYSTEM

DEFENSE AMMUNITION LOGISTICS ACTIVITY

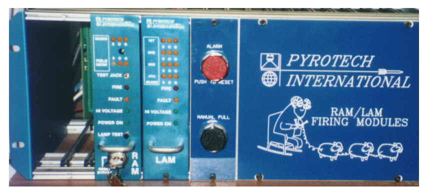
## DELUGE SYSTEM COMPONENTS

**RESPONSE TIME**

- **MULTI-SPECTRUM HIGH-SPEED FLAME DETECTORS**

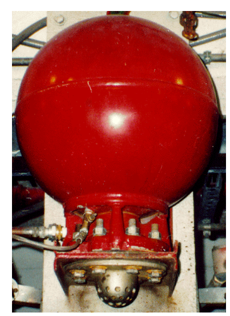
**3-5 ms**

- **RAM-LAM CONTROLLER**




**< 0.2 ms**

- **SQUIB ACTUATED, HIGH-RATE DISCHARGE SPHERE (10 & 30 LITER)**



**2- 4 ms**

# ADVANCED FIRE PROTECTION DELUGE SYSTEM

## FIRE DETECTION

**Detector Response Time (ms) from the Detectable Event**

| | Fast Fire Propagation ⟷ | | | | | Slow Fire Propagation |
|---|---|---|---|---|---|---|---|
| **DETECTOR** | **M206 IR Flare** | **MK875 Delay Comp.** | **MK25 Starter Comp.** | **M125 Illum. Comp.** | **M18 Green Smoke** | **M18 Yellow Smoke** | **First Fire Type I** |
| **Dual Spectrum (IR/IR)** | 7 | 17 | 31 (1)* | 30 (2)* | 60 (3)* | 57 | 91 (4)* |
| **Fire Sentry (UV/IR)** | 6 | 12 | 28 | 40 (3)* | 48 | 67 | 64 (1)* |
| **Spectrex (UV/IR)** | 5 | 19 | 44 (6)* | 56 (7)* | 80 (4)* | 83 (2)* | 97 (5)* |
| **Det Tronics (UV)** | 11 | 21 (1)* | 27 (1)* | 20 | 53 | 59 | 31 |

* - Number of events missed are listed in parenthesis.
Times were measured with ¼ lb.of material. Detectors located 36" above.

**NOTE: DETECTOR RESPONSE TIME IS DIRECTLY RELATED TO MATERIAL FLAME PROPAGATION RATE**

# ADVANCED FIRE PROTECTION DELUGE SYSTEM

## FALSE ALARM ANALYSIS

**Maximum Detector False Alarm Distance to a False Alarm Source**

| SOURCE | Minimum Distance Tested | Dual Spectrum (IR/IR) | Fire Sentry (UV/IR) | Spectrex (UV/IR) | Detector Electronics (UV) |
|---|---|---|---|---|---|
| Butane Lighter | 3 in | **6 in** | **1 ft** | **3 in** | **16 ft** |
| Floodlight (650W) | 2 ft | DN* | **2 ft** | DN | **2 ft** |
| Incandescent 75W | 1 in | **6 in** | DN | DN | **6 in** |
| Philips EarthLight | 1 in | **1 in** | DN | DN | DN |
| Floodlight (75W) | 1 in | **1 in** | DN | DN | DN |
| 3/8”, 120VAC Drill | 1 in | DN | DN | DN | **15 ft** |
| 1-inch Electric Arc | 1 in | DN | DN | DN | **16 ft** |
| Arc Welding | 3 ft | **3 ft** | **6 ft** | DN | **24 ft** |
| Acetylene Torch | 3 ft | **3 ft** | **12 ft** | **3 ft** | **12 ft** |
| Grinding mild steel | 3 ft | DN | **3 ft** | DN | DN |

*DN - Did Not alarm

# ADVANCED FIRE PROTECTION DELUGE SYSTEM

DEFENSE AMMUNITION LOGISTICS ACTIVITY

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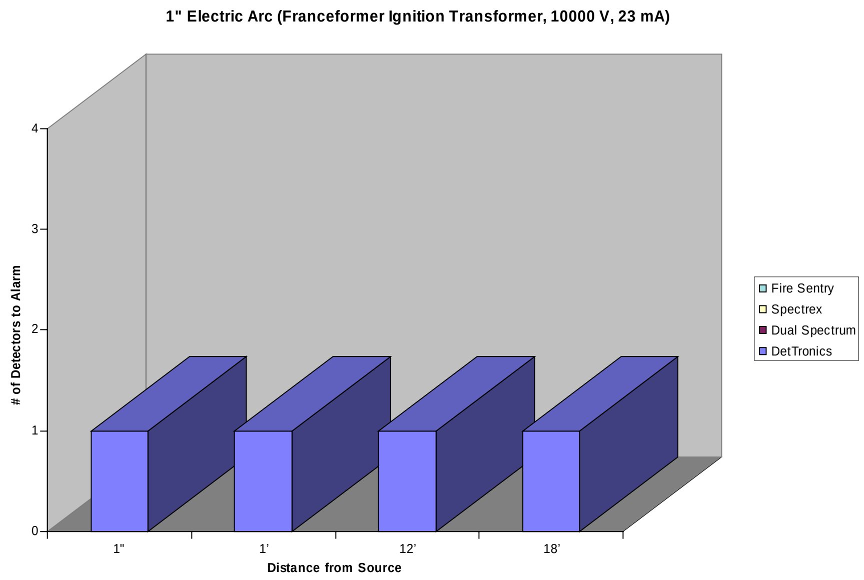
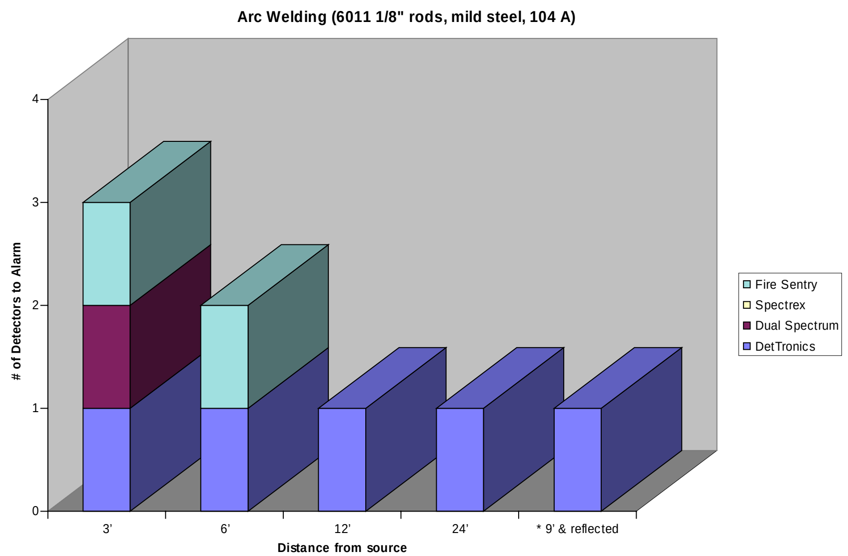
## FALSE ALARM ANALYSIS




* The welding source was reflected off of a smooth painted wall

# ADVANCED FIRE PROTECTION DELUGE SYSTEM

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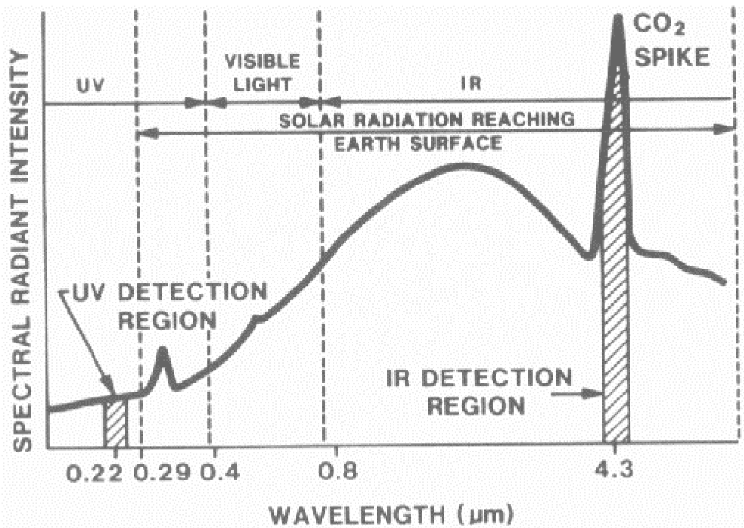
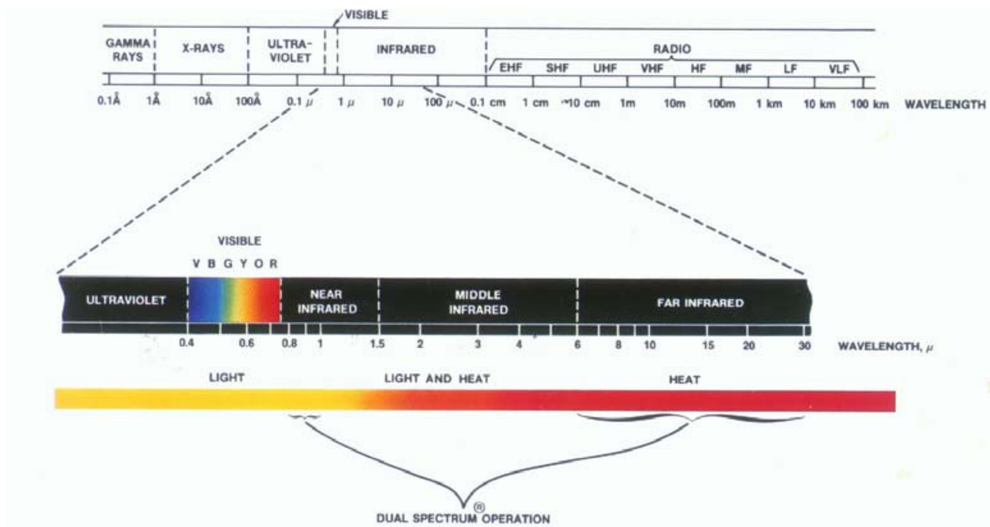
U.S. Army Industrial Operations Command

DEFENSE AMMUNITION LOGISTICS ACTIVITY

## SPECTRAL ANALYSIS




TYPICAL HYDROCARBON FIRE EMISSION SPECTRUM
SHOWING DETECTION REGIONS OF OMNIGUARD 730



# ADVANCED FIRE PROTECTION DELUGE SYSTEM

DEFENSE AMMUNITION LOGISTICS ACTIVITY

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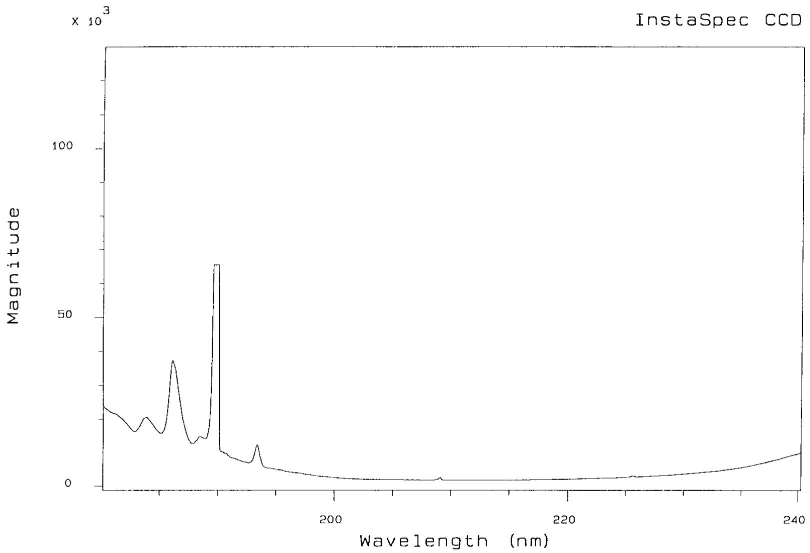
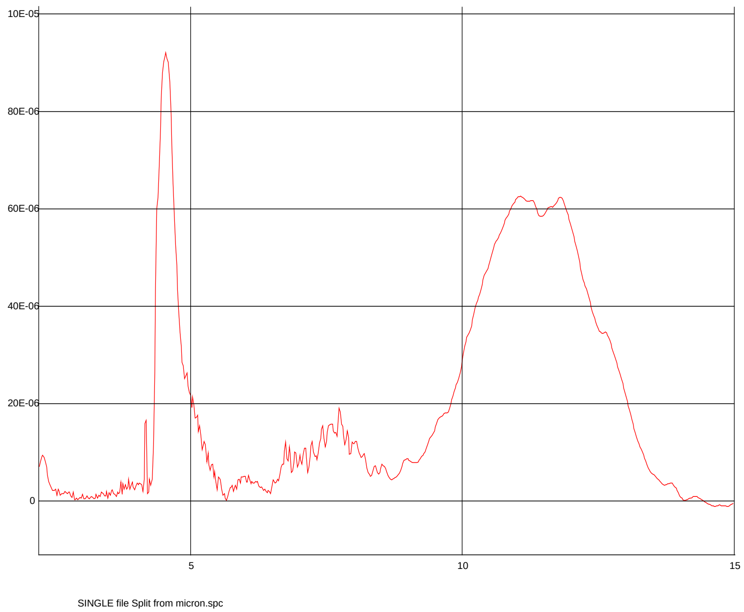
## LKL PROPELLANT SPECTRAL ANALYSIS



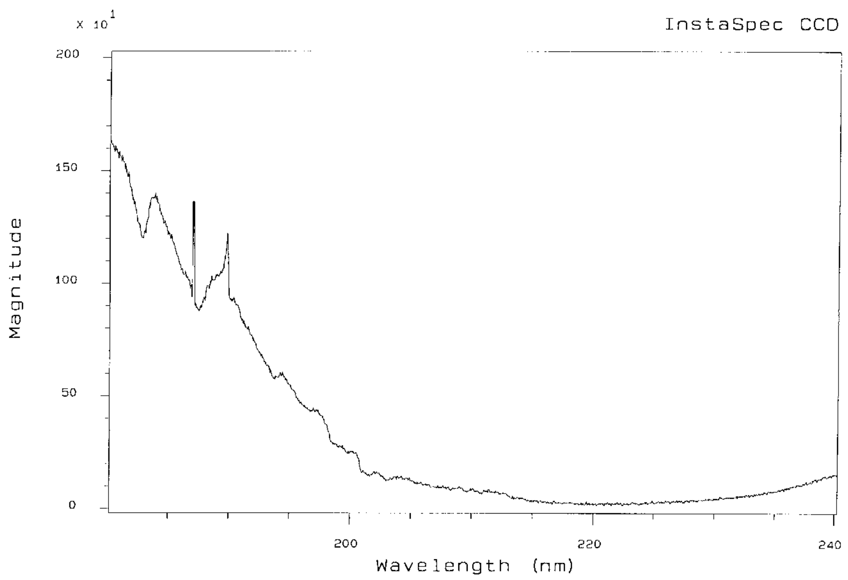

UV SPECTRA

IR SPECTRA



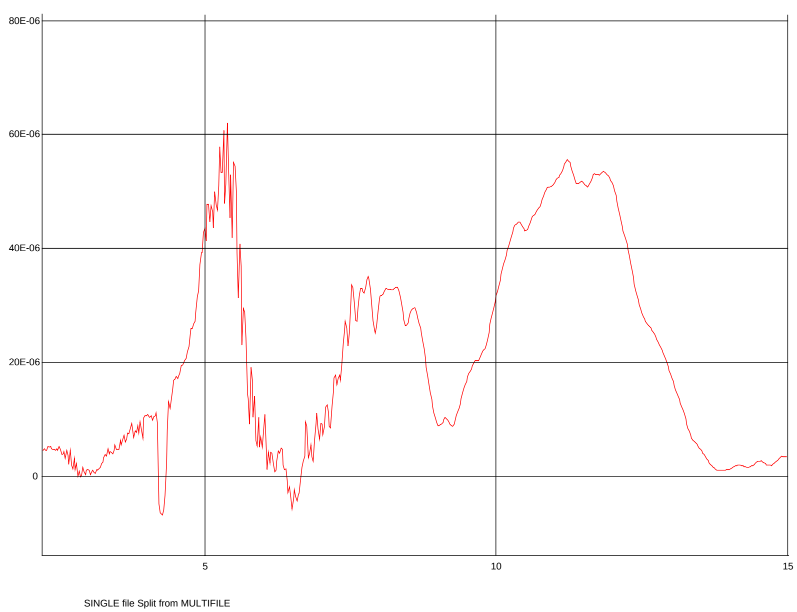
# ADVANCED FIRE PROTECTION DELUGE SYSTEM

## RS-41 SPECTRAL ANALYSIS




UV SPECTRA

IR SPECTRA



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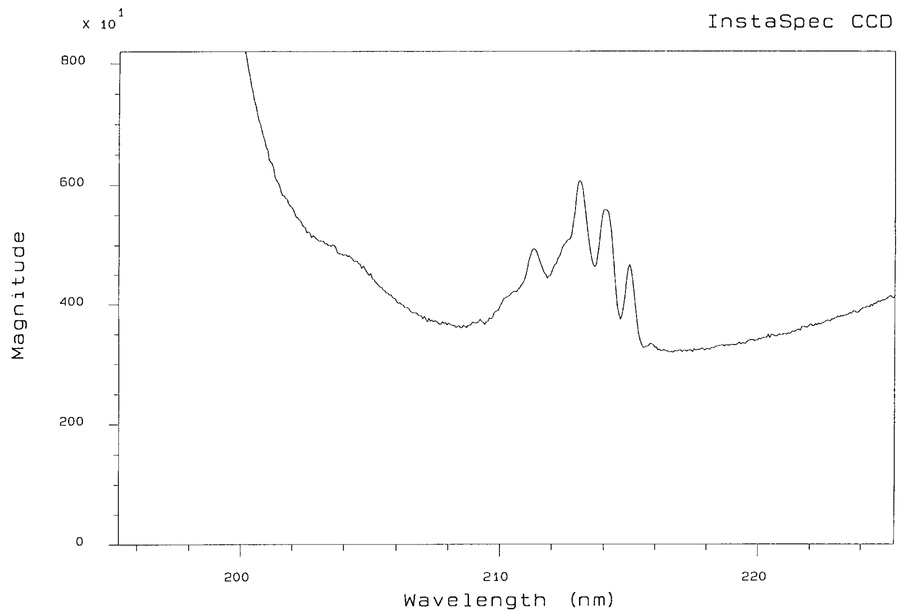
# ADVANCED FIRE PROTECTION DELUGE SYSTEM

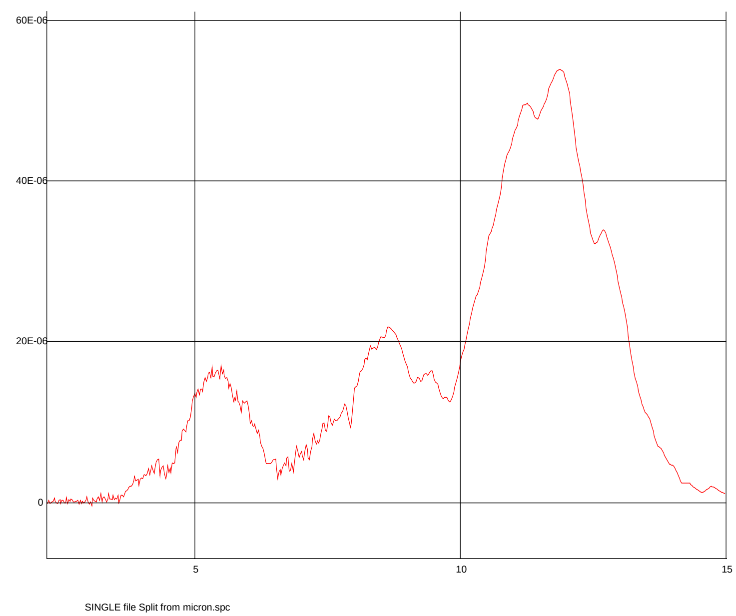
DEFENSE AMMUNITION LOGISTICS ACTIVITY

## M206 SPECTRAL ANALYSIS



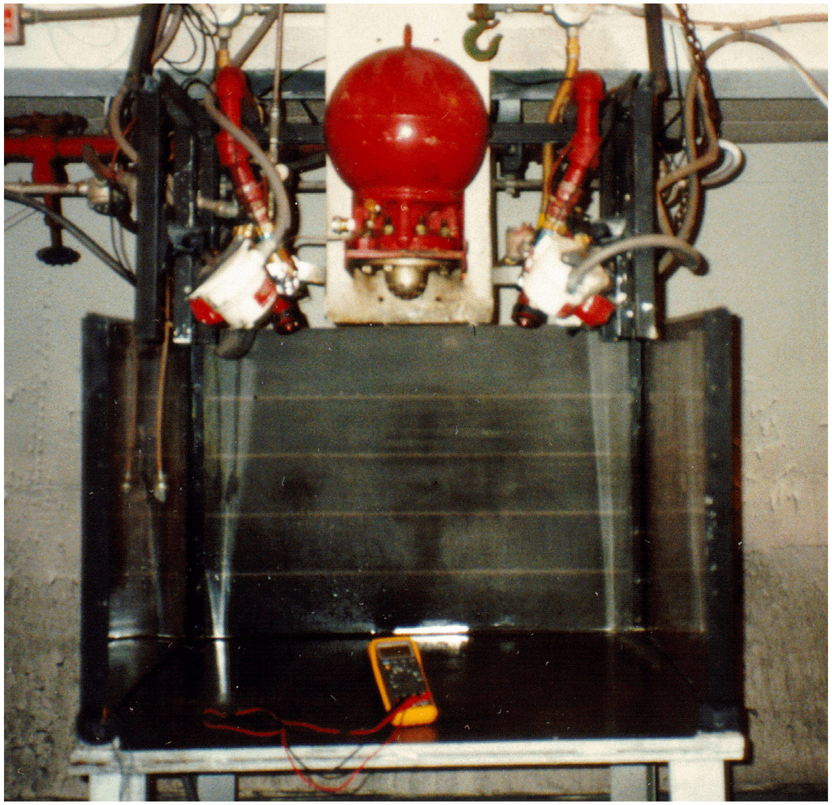

UV SPECTRA

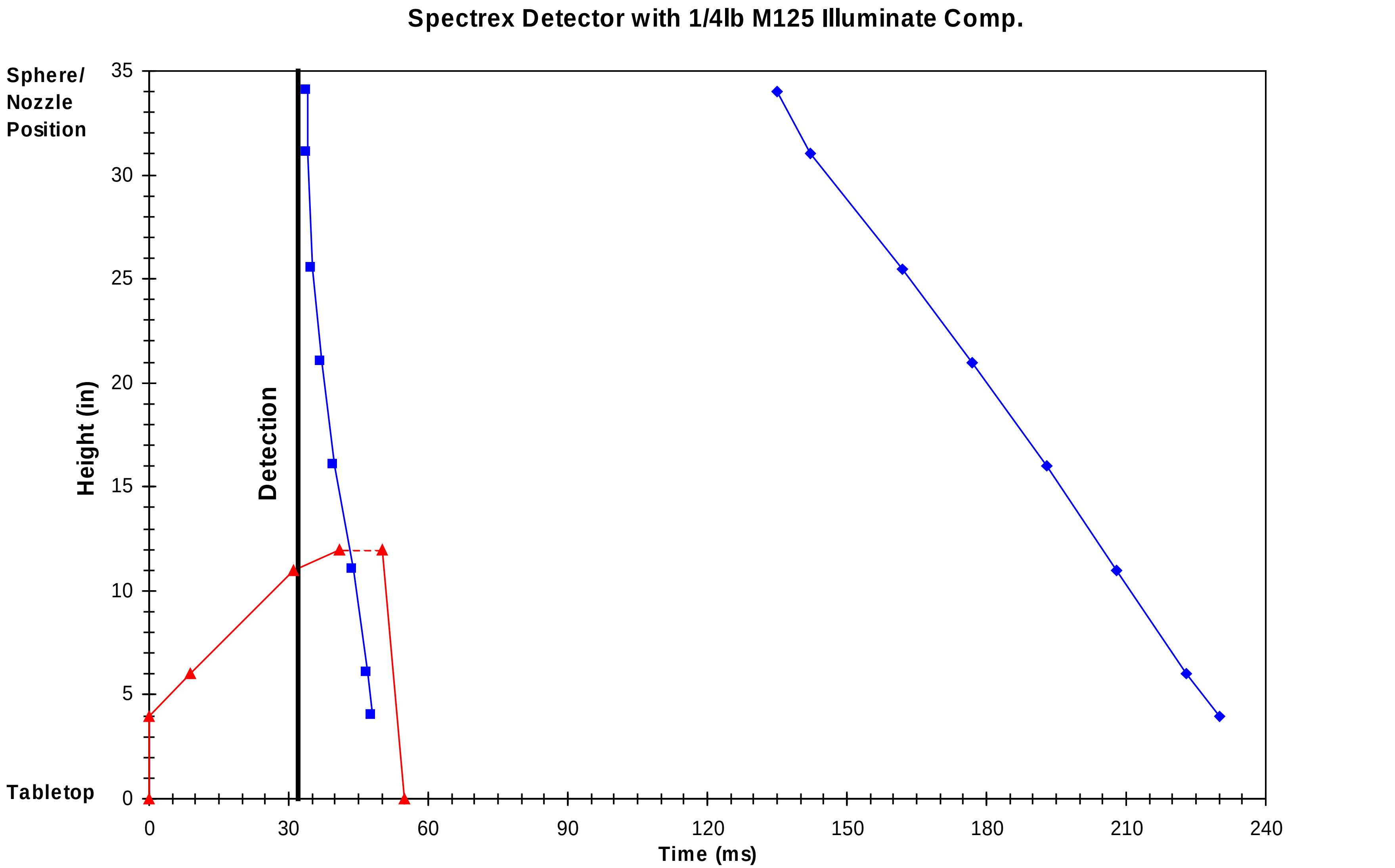
IR SPECTRA



# ADVANCED FIRE PROTECTION DELUGE SYSTEM

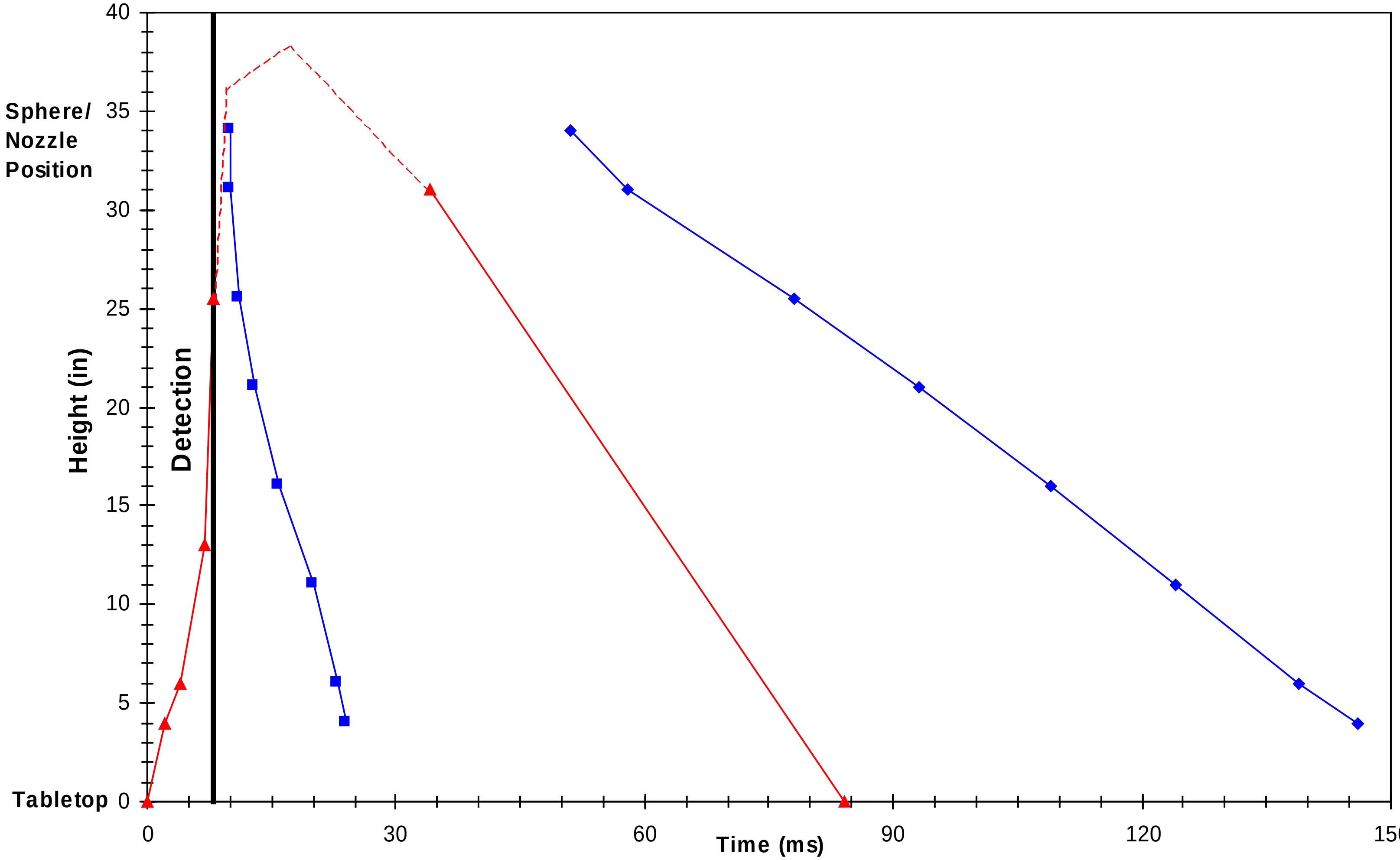
## DELUGE TABLETOP SETUP



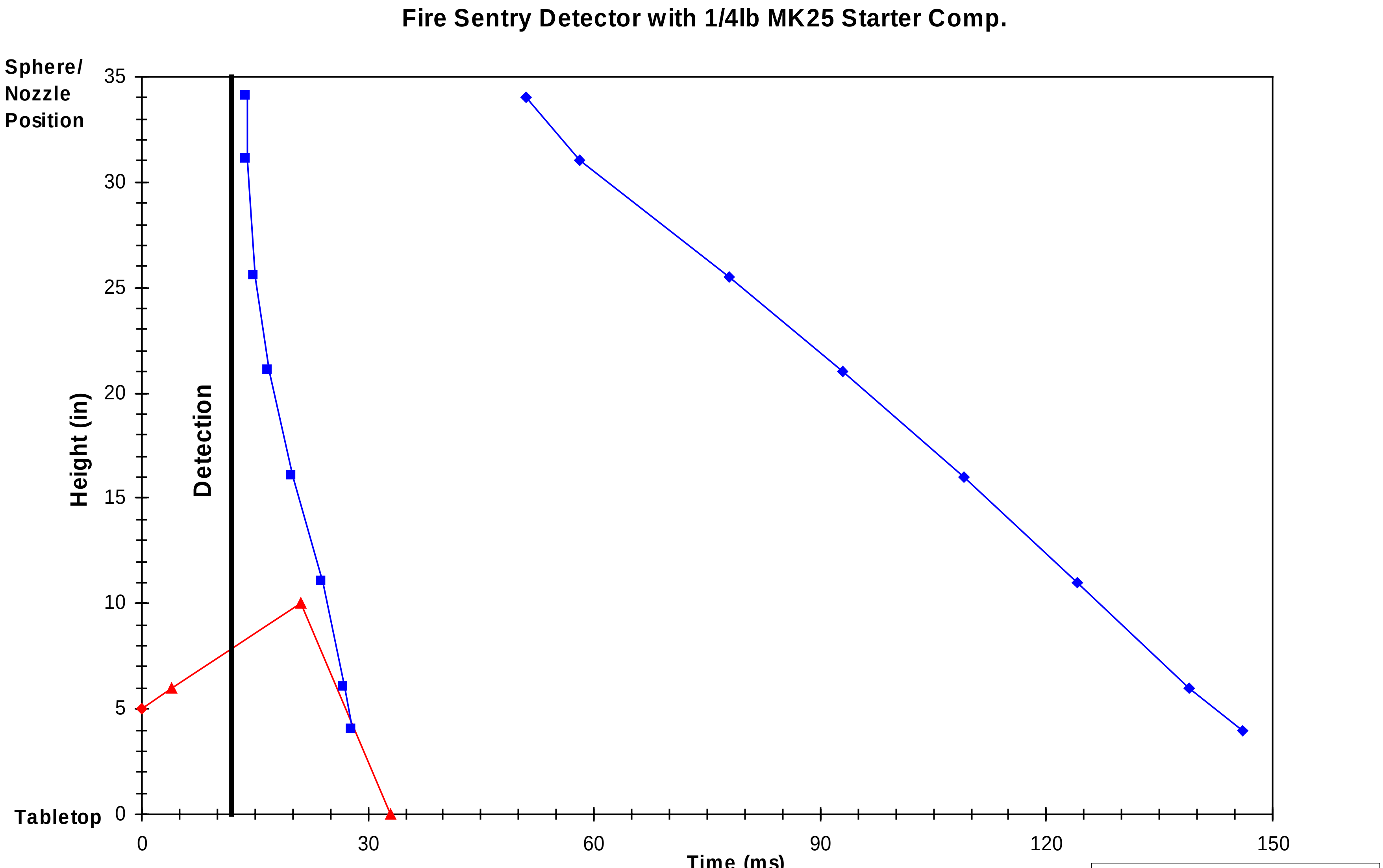



Time 0 is the Detectable Event. This graph presents a combination of data from one complete test including: 1) Fire propagation, 2) Detection time, 3) Sphere water discharge, and 4) Follow-on water discharge. Sphere water and follow-on water discharge curves represent the average response for all tests. Flame propagation shown as a dotted line is estimated. It could not be measured due to obscuration of the high speed camera.

**Dual Spectrum Detector with 1/4lb Red Lead**

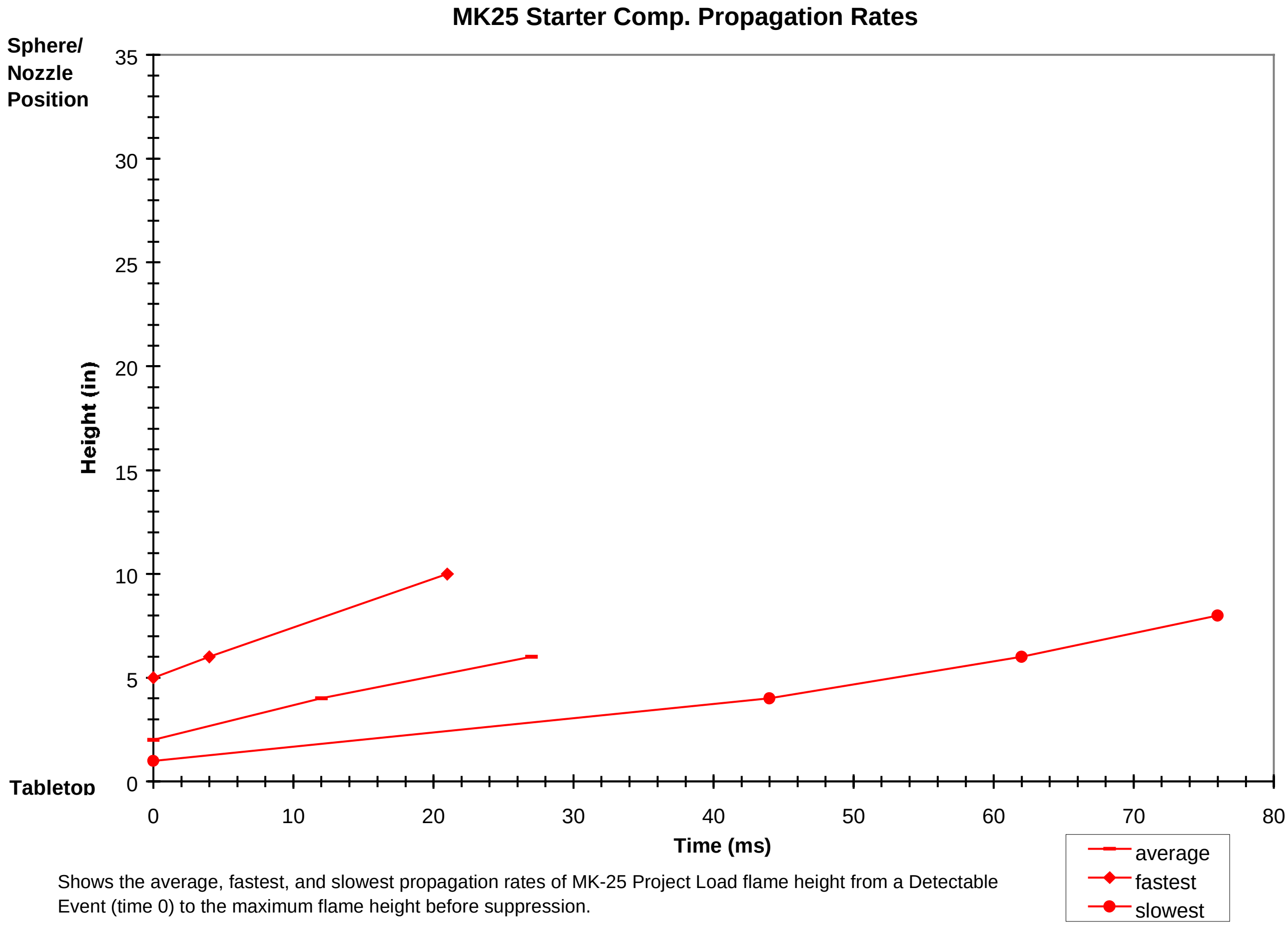



Time 0 is the Detectable Event. This graph presents a combination of data from one complete test including: 1) Fire propagation, 2) Detection time, 3) Sphere water discharge, and 4) Follow-on water discharge. Sphere water and follow-on water discharge curves represent the average response for all tests. Flame propagation shown as a dotted line is estimated. It could not be measured due to obscuration of the high speed camera.

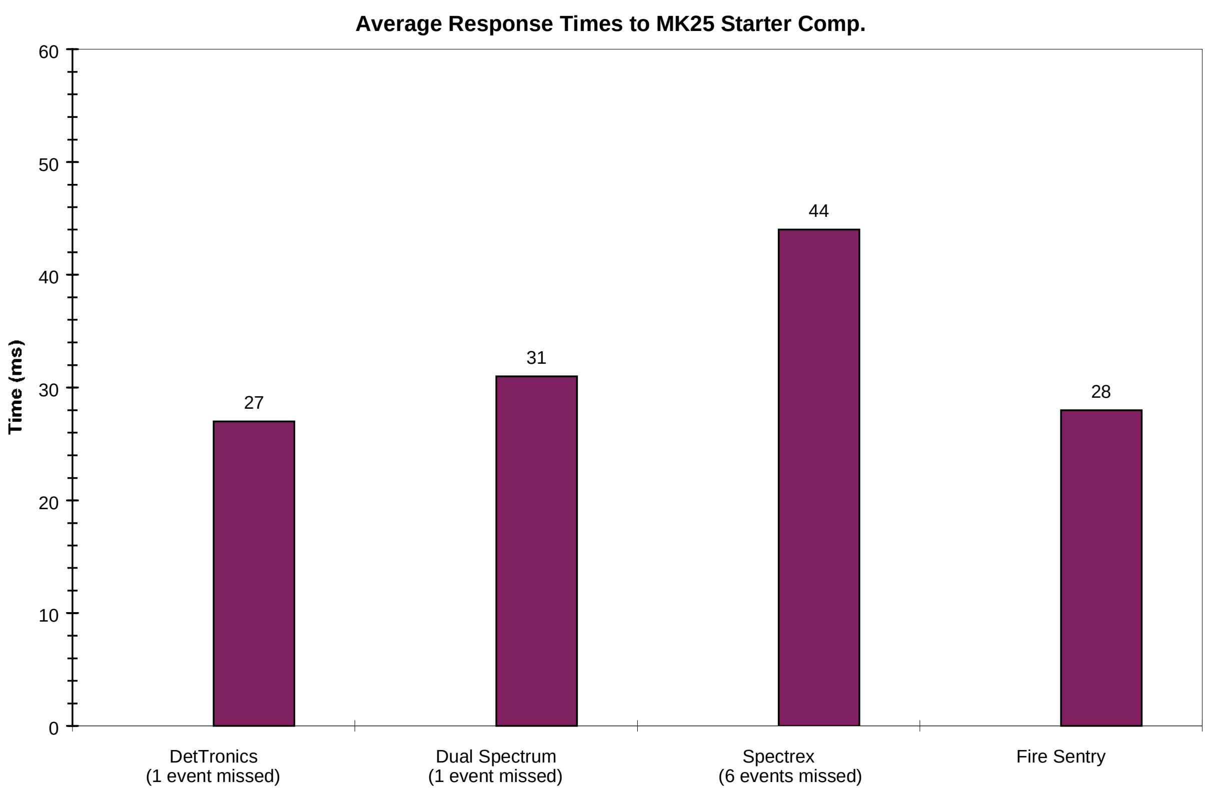



Time 0 is the Detectable Event. This graph presents a combination of data from one complete test including: 1) Fire propagation, 2) Detection time, 3) Sphere water discharge, and 4) Follow-on water discharge. Sphere water and follow-on water discharge curves represent the average response for all tests.

# PROPAGATION RATE AND DETECTOR RESPONSE TIME



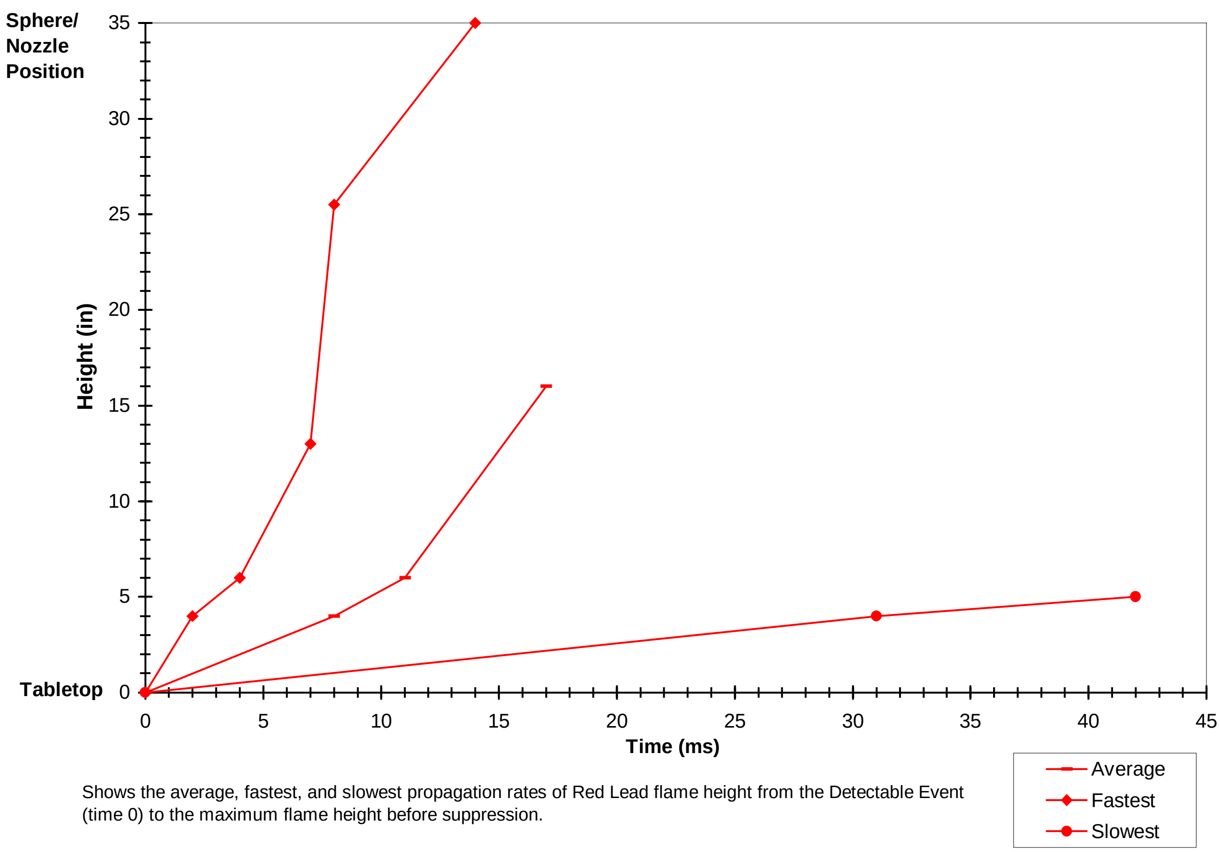

Shows the average, fastest, and slowest propagation rates of MK-25 Project Load flame height from a Detectable Event (time 0) to the maximum flame height before suppression.




This graph shows each detector's average response time from the detectable event (time 0).
There were ten (10) total events. Events missed were due to water obscuration.

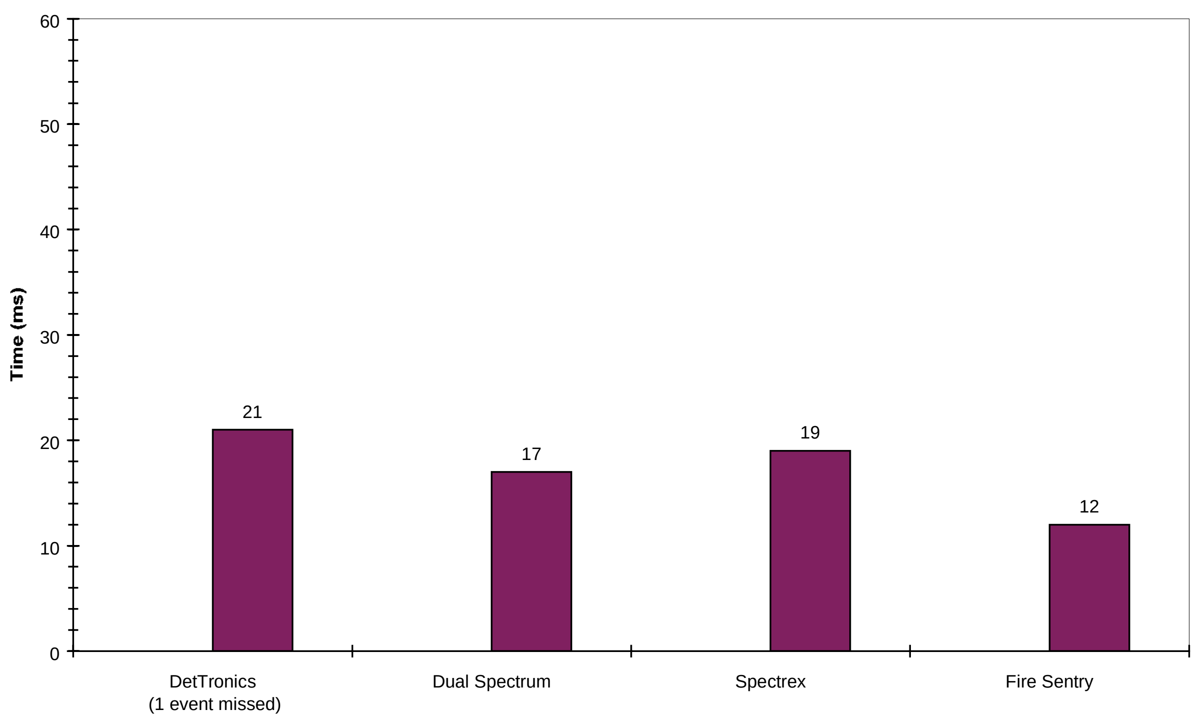
# PROPAGATION RATE AND DETECTOR RESPONSE TIME

## Red Lead Propagation Rates



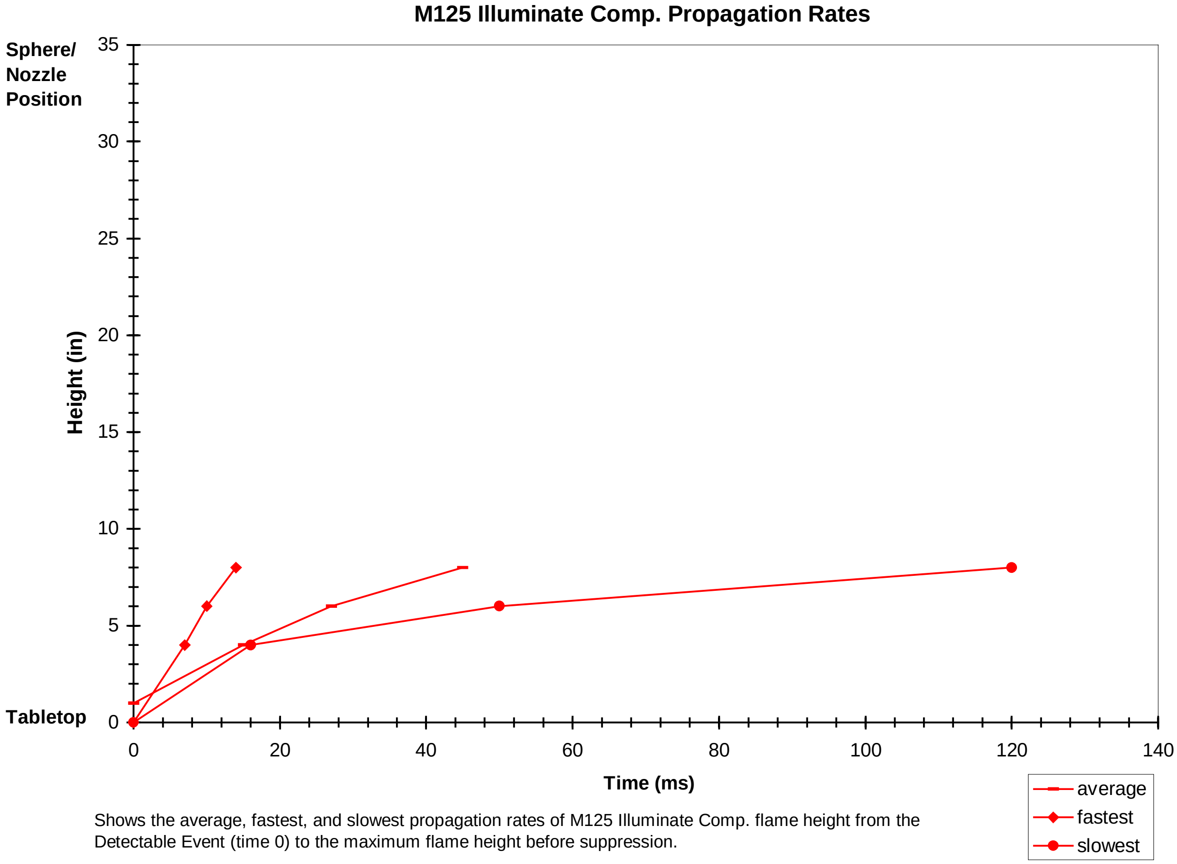

Shows the average, fastest, and slowest propagation rates of Red Lead flame height from the Detectable Event (time 0) to the maximum flame height before suppression.

## Average Response Times to Red Lead

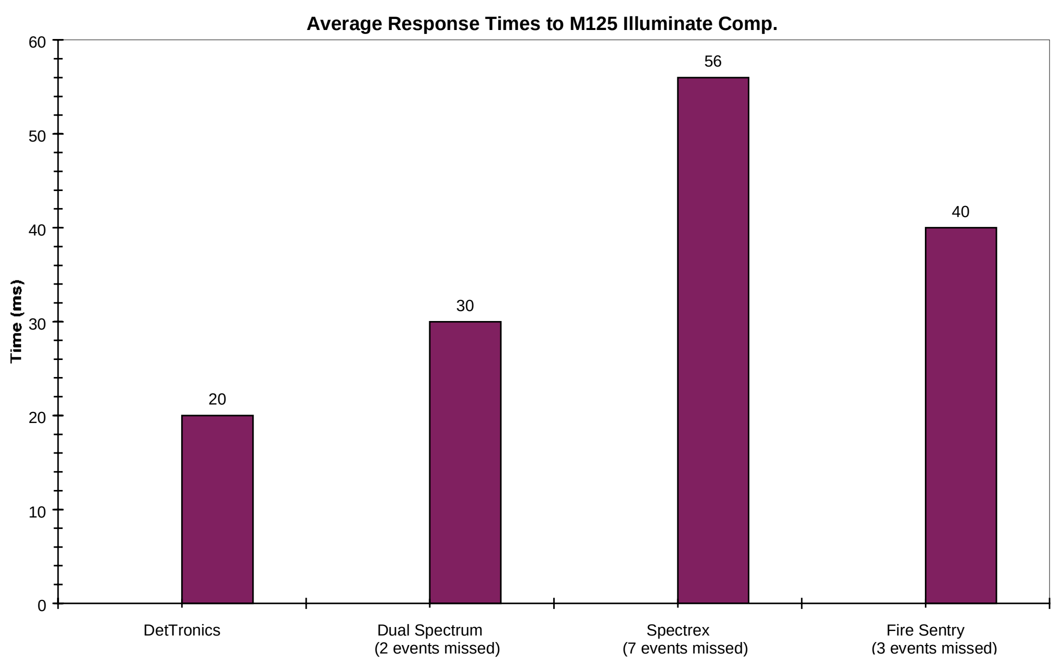



This graph shows each detector's average response time from the detectable event (time 0).
There were fourteen (14) total events. Events missed were due to water obscuration.

# PROPAGATION RATE AND DETECTOR RESPONSE TIME

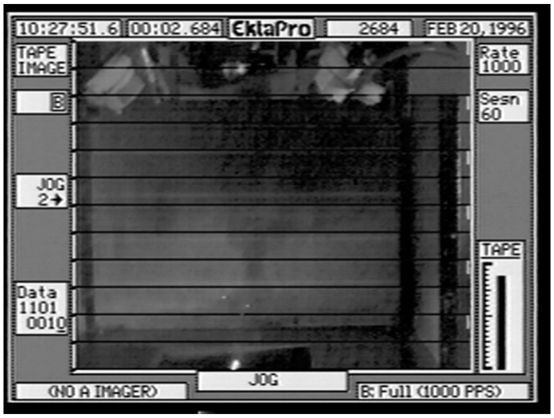



Shows the average, fastest, and slowest propagation rates of M125 Illuminate Comp. flame height from the Detectable Event (time 0) to the maximum flame height before suppression.

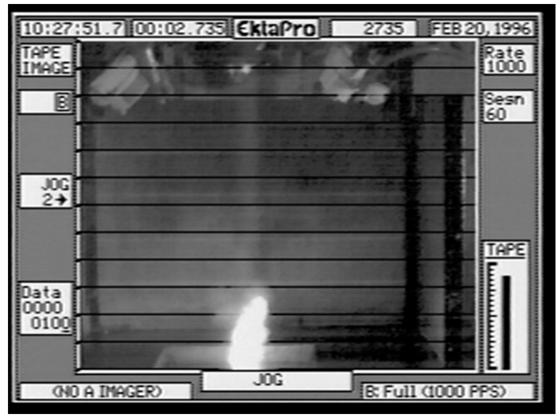



This graph shows each detector's average response time from the detectable event (time 0).
There were twelve (12) total events. Events missed were due to water obscuration.

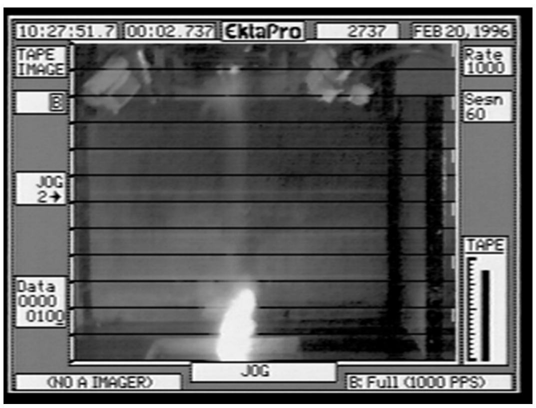
# High Speed Video Data Collection
## M125 Illuminate Composition



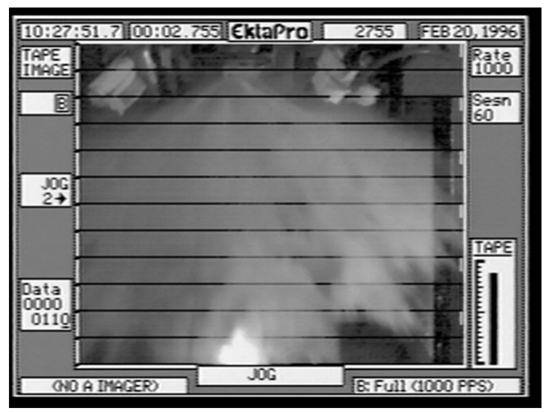

**Detectable Event**
(532 ms after match initiation)
(Time 0 on Charts)



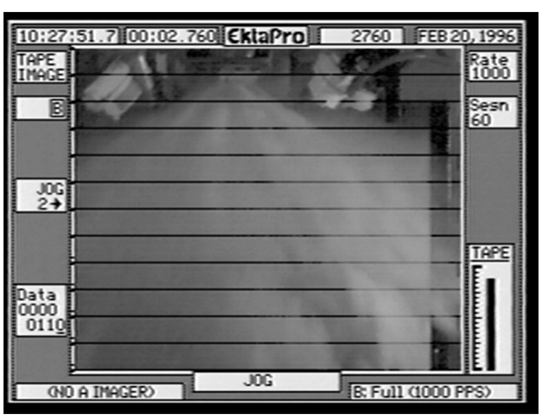

**Detection**
(58ms after Detectable Event)
(Flame 8 inches High)



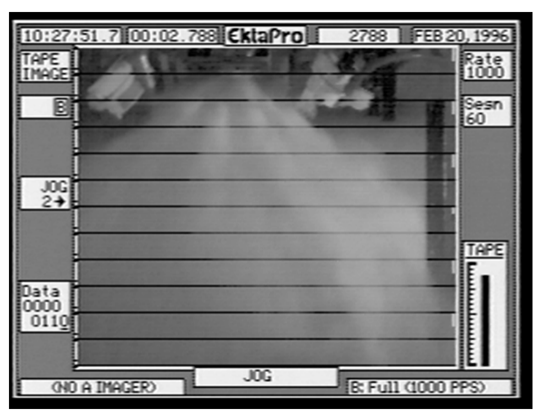

**Sphere Discharge**
(2 ms after Detection)
(Water 35 inches above Tabletop)




**Water on Table Top**
(18 ms after Detection)
(Water 0 inches above Tabletop)

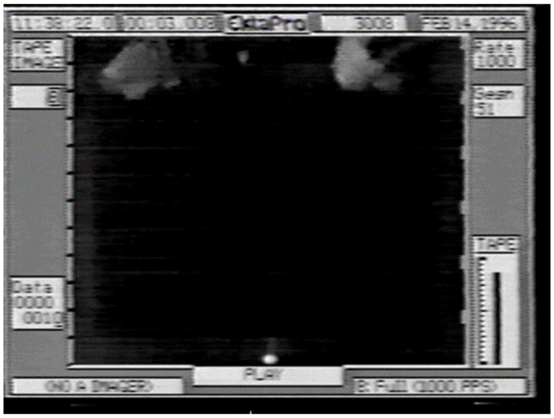



**Extinguishment**
(23 ms after Detection)
(Fire at 0 inches)

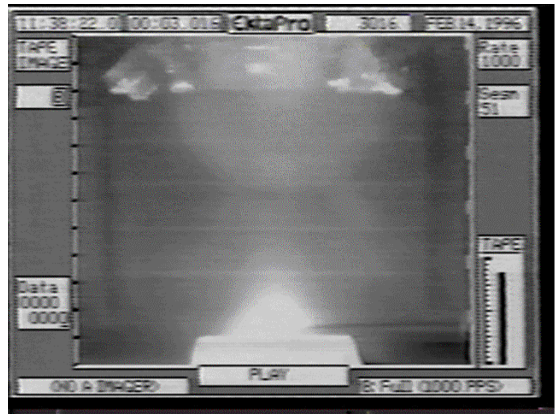



**Follow-on Water Discharge**
(41 ms after Detection)
(Follow-on Water at 35 inches above Tabletop)

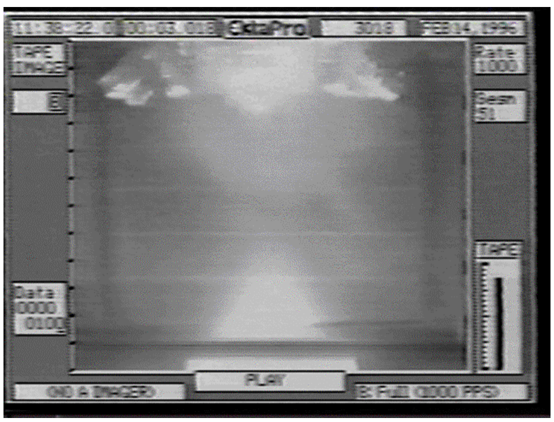
# High Speed Video Data Collection
## Red Lead



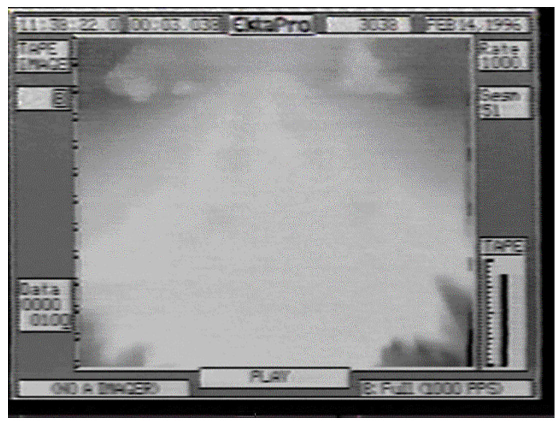

**Detectable Event**
(9 ms after match initiation)
(Time 0 on Charts)



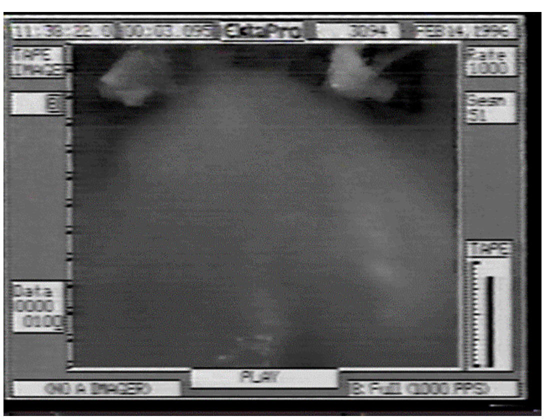

**Detection**
(9 ms after Detectable Event)
(Flame 11 inches High)



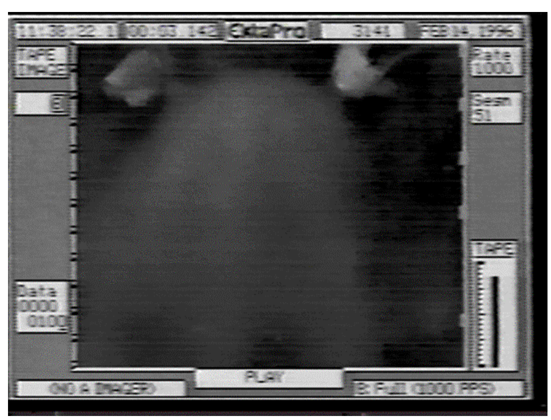

**Sphere Discharge**
(2 ms after Detection)
(Water 35 inches above Tabletop)




**Water on Table Top**
(22 ms after Detection)
(Water 0 inches above Tabletop)




**Follow-on Water Discharge**
(74 ms after Detection)
(Follow-on Water at 35 inches above Tabletop)




**Extinguishment**
(124 ms after Detection)
(Fire at 0 inches)